

That it is astigmatism with the rule
and that it is corrected by a
minus cyl. axis in the
principal meridian.

When the images are separated

ACCOMMODATIVE CONVERGENCE

AND

FUSION CONVERGENCE

in the vertical or secondary
position it shows that it is
against the rule astigmatism
and that the vertical is
weaker in dioptric power
than the horizontal and
that it is corrected by a minus
cyl. axis in the secondary
position.

Place movable repointer
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Accommodative Convergence
and
Fusion Convergence

Second Edition

Carl F. Shepard Memorial Library
Illinois College of Optometry

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South Bridge, Massachusetts, U. S. A.

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Accommodation and Convergence

Accommodative Convergence and Fusion Convergence.

Accommodation—That function of the eye which permits an increase of refractive power so that objects nearer than infinity may be clearly seen. Also used to overcome latent and manifest hyperopia in the interests of clear vision.

Convergence—That function of the eyes which turn the visual axes in, so that objects nearer than infinity may be seen singly, also used to overcome heterophoric conditions in the interests of binocular single vision.

Accommodative Convergence—That amount of convergence which is directly associated with the act of accommodation.

Fusion Convergence—That amount of convergence supplied by the Fusion Faculty in the interests of binocular single vision.

When a pair of eyes that are orthophoric and emmetropic, and not presbyopic, change the point of fixation from infinity to, say, one third of a meter, a dual function is performed by the eyes. Accommodation is used so that the object of regard may be seen clearly and convergence is used so that the object of regard may be seen singly. The ratio of convergence to accommodation is supposed to be three to one. That is to say, 3Δ of convergence to 1.00 D. of accommodation, calculated as follows:

P. D. of 60 mm. To displace light one half of this 60 mm, *i. e.* 30 mm, at a distance of one third of a meter or 333 mm, would need a 9Δ prism. This is equivalent to the turning, in prism diopters, of one eye. Two eyes would be 18Δ . The accommodation supposed to be used for one third of a meter is 3.00 D. for each eye, or for the two eyes 6.00 D. Then the ratio between 18 and 6.00 is three to one. It can

readily be seen that, with a narrower P. D. than 60 mm, the convergence necessary to see single at thirteen inches is less than 18Δ .

To determine quickly the number of prism diopters of convergence necessary to see single at any given distance we may use the Prentice¹ rule—"Read the patient's interpupillary distance in centimeters, when half of it will indicate the prism diopters required to substitute one meter angle for each eye.

Therefore if P. D. is 55 mm then half in centimeters is 2.75, and for one third of a meter (three meter angles) would be $2.75 \times 3 = 8.25\Delta$ for each eye and 16.5Δ for the two eyes. Using this rule as a basis for one third of a meter we can abbreviate it as follows: Multiply patient's P. D. in centimeters by 3.

For handy reference we show on next page the prism diopters of convergence necessary to see single at distances from 26 inches (two thirds of a meter) to 10 inches (one quarter of a meter), and for P. D.'s from 55 mm to 75 mm.

It is obvious that the wider the P. D. the greater the amount of convergence necessary to see single at any near point. Also it is obvious that the shorter the reading distance the more the eyes have to turn in to maintain binocular single vision. Both of these items, *i. e.*, P. D. and working distance, are important when near work is attempted for any length of time.

Normally when a pair of eyes emmetropic for distance, use convergence for, say, thirteen inches, about two thirds of the convergence supplied is directly associated with the act of accommodation (accommodative convergence), and about one third is supplied by the fusion faculty (fusion convergence).

Various authorities, such as Howe, Maddox, Von Graefe, Theobald, Sheard, and others, have made exhaustive tests at the regular reading distance, and all results show

¹ Page 114—Ophthalmic Lenses by Prentice.

INTER-PUPILLARY DISTANCE IN MILLIMETERS

| Fixation Distance | 50 | 53 | 55 | 56 | 57 | 58 | 59 | 60 | 61 | 62 | 63 | 64 | 65 | 66 | 67 | 68 | 69 | 70 | 71 | 72 | 73 | 74 | 75 |
|---|------|-------|-------|------|-------|------|-------|------|-------|------|-------|------|-------|------|-------|------|-------|------|-------|------|-------|-------|-------|
| 26 Inches 2/3 Meter 1½ Meter Angles | 7.5 | 7.95 | 8.25 | 8.4 | 8.55 | 8.7 | 8.85 | 9.0 | 9.15 | 9.30 | 9.45 | 9.60 | 9.75 | 9.90 | 9.95 | 10.2 | 10.35 | 10.5 | 10.65 | 10.8 | 10.95 | 11.10 | 11.25 |
| 20 Inches ½ Meter 2 Meter Angles | 10.0 | 10.6 | 11.0 | 11.2 | 11.4 | 11.6 | 11.8 | 12.0 | 12.2 | 12.4 | 12.6 | 12.8 | 13.0 | 13.2 | 13.4 | 13.6 | 13.8 | 14.0 | 14.2 | 14.4 | 14.6 | 14.8 | 15.0 |
| 16 Inches 2/5 Meter 2½ Meter Angles | 12.5 | 13.25 | 13.75 | 14.0 | 14.25 | 14.5 | 14.75 | 15.0 | 15.25 | 15.5 | 15.75 | 16.0 | 16.25 | 16.5 | 16.75 | 17.0 | 17.25 | 17.5 | 17.75 | 18.0 | 18.25 | 18.5 | 18.75 |
| 13 Inches ⅓ Meter 3 Meter Angles | 15.0 | 15.9 | 16.5 | 16.8 | 17.1 | 17.4 | 17.7 | 18.0 | 18.3 | 18.6 | 18.9 | 19.2 | 19.5 | 19.8 | 20.1 | 20.4 | 20.7 | 21.0 | 21.3 | 21.6 | 21.9 | 22.2 | 22.5 |
| 10 Inches ¼ Meter 4 Meter Angles | 20.0 | 21.2 | 22.0 | 22.4 | 22.8 | 23.2 | 23.6 | 24.0 | 24.4 | 24.8 | 25.2 | 25.6 | 26.0 | 26.4 | 26.8 | 27.2 | 27.6 | 28.0 | 28.4 | 28.8 | 29.2 | 29.6 | 30.0 |

AND FUSION CONVERGENCE

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that normally about 4 to 6 Δ of exophoria is manifest at the near point. It is called exophoria because it is measured with a prism base in. Accommodative exophoria is probably a better name, or simply fusion convergence in use. So consistently does the average normal person with comfortable vision show from 4 to 6 Δ of exophoria at near that such an amount of exophoria is referred to as physiologic or normal.

To measure this exophoria or fusion convergence at near some device to break fusion is employed. The single displacing prism recommended by Savage, or the double prism recommended by Maddox are the best for general use.

The Savage displacing prism is one of 6 Δ placed base up, usually over the non-dominating eye. This breaks fusion vertically, so any fusion convergence used by the patient in the act of reading at, say, thirteen inches, is inactive. To make sure that accommodative convergence (if any) is in action a line of type such as —“Read these words letter by letter,” is employed. The patient must use accommodation to read the letters unless he or she is presbyopic and then sufficient plus sphere is added to the distance correction to permit clear vision. It may be noted here that the test is made with the patient's ametropic correction before the eyes.

With the card set at thirteen inches, and the 6 Δ displacing prism in position before the left eye, the patient will see two lines of type unless there is a considerable right hyperphoria. If the two spots at the left of each line are directly above each other there is no exophoria at near, or in other words, the eyes are converging for thirteen inches when fusion is suspended; therefore, all the convergence is accommodative convergence.

- Read these Words Letter by Letter
- Read these Words Letter by Letter

Fig. 1. The above shows a condition of no exophoria using the 6 Δ displacing prism.

If the upper spot seen by the right eye is off to the left hand side of the lower spot seen by the left eye, there is a condition of exophoria, and the amount of prism base in necessary to place the spots directly above each other is a measure of the amount. Suppose it takes 6Δ base in to align the spots, this means that when reading at thirteen inches 6Δ of the convergence used by that patient is fusion convergence. The balance is accommodative convergence. If the P. D. is 60 mm and patient is orthophoric for distance 18Δ of convergence are used at one third of a meter, divided as follows:

| | |
|---------------------------|------------|
| Total Convergence in use | 18Δ |
| Fusion Convergence in use | 6Δ |
| <hr/> | |
| Accommodative Convergence | |
| in use | 12Δ |

● Read these Words Letter by Letter

● Read these Words Letter by Letter

Fig. 2. Showing a condition of exophoria at thirteen inches using the Savage 6Δ displacing prism before the left eye.

If the upper spot seen by the right eye is to the right of the lower spot seen by the left eye there is a condition of esophoria at near, and the amount of prism base out to align the spots is a measure of the error. Suppose it takes 4Δ base out to align the spots, P. D. of 60 mm and card at thirteen inches, then the patient has a tendency to over converge and all the convergence necessary to see single at thirteen inches (18Δ) plus 4Δ , a total of 22Δ is associated with the act of accommodation, (accommodative convergence). In such a case the positive form of fusion convergence takes no part in near work.

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● Read these Words Letter by Letter

Fig. 3. Showing a condition of accommodative esophoria at near using the 6Δ displacing prism before the left eye.

The Maddox Double Prism is a splendid device for breaking the fusion and making the accommodative convergence test. Usually it reveals from 2Δ to 5Δ more exophoria than the displacing prism. As both tests are very quickly made the author uses both, thereby obtaining two opinions.

The Maddox Double Prism must be set in the instrument so that the base line is precisely horizontal, and exactly bisecting the pupil. A good method is to occlude the right eye, place double prism in position and ask patient if two lines of type are visible. If not, adjust height of instrument until the lines are equally clear. Next ask patient if the two spots are directly above each other, if not, it means that the base line of double prism is not exactly horizontal and should be turned until spots are above each other. The right eye is now uncovered, and the patient will see a third line in between the other two unless there is considerable vertical imbalance. If the three spots are in a vertical line there is no accommodative exophoria at the near point.

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Fig. 4. Showing a condition of no accommodative exophoria using the Maddox Double Prism.

If the center spot seen by the right eye is to the left of the other two seen by the left eye, there is a condition of accommodative exophoria, and the amount of prism base in to align the spots is a measure of the error.

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Fig. 5. Showing a condition of exophoria at near using the Maddox Double Prism before the left eye.

If the center spot seen by the right eye is to the right of the other two seen by the left eye, there is a condition of accommodative esophoria, and the amount of prism base out to align the spots is the measure of the error.

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- Read these Words Letter by Letter

Fig. 6. Showing a condition of accommodative esophoria at near using the Maddox Double Prism before the left eye.

The Maddox Double Prism is also a splendid test to determine the amount (if any) of vertical imbalance at the near point. When the lateral imbalance has been located and corrected the center spot will be exactly midway between the other two when there is no vertical imbalance.

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- Read these Words Letter by Letter

Fig. 7. Showing an absence of vertical imbalance at the near point using the Maddox Double Prism.

If the center spot seen by the right eye is nearer the upper spot, the left eye is turning up or the right eye down (left hyperphoria). The amount of prism base down before O. S. or base up before O. D. is a measure of the error.

- Read these Words Letter by Letter
- Read these Words Letter by Letter
- Read these Words Letter by Letter

Fig. 8. Showing a condition of left hyperphoria using the Maddox Double Prism before the left eye.

We have endeavored to make it clear that normally convergence is supplied from two sources, namely—That associated with the act of accommodation (accommodative

convergence) and that supplied by the fusion faculty, (fusion convergence). The amount of exophoria revealed at the near point is the amount of fusion convergence which is used to maintain binocular single vision. When this exophoria is large it means that the fusion convergence bears the greatest burden in the act of seeing single at the close points. When there is little or no exophoria and in esophoria, the burden of binocular single vision is on the accommodative centers.

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Fig. 9. Vertical line of type used in making the positive and negative reserve fusion convergence tests.

The accommodative convergence tests as outlined supplies information as to the demands on the convergence. The next consideration is the reserves of convergence. There is the positive reserve fusion convergence and the negative reserve fusion convergence.

The positive reserve corresponds to the adduction at distance, and is the reserve fusion convergence over and above what is being used in the interests of binocular

single vision. It is measured by having the patient fix a vertical line of type, while prism power base out is turned before the eyes until diplopia ensues. In non-presbyopic patients the vertical line of type usually blurs before it doubles. This means that more accommodation than is actually necessary to see clearly is being used by the patient. This extra accommodation has its associated accommodative convergence. Therefore, in the opinion of the writer such convergence should not be considered and recorded as fusion convergence, because it is not available to the patient unless the extra accommodation is allowed to function.

Our method of taking and recording the positive reserve is to ascertain the greatest amount of prism base out that can be overcome by the patient, the line of type remaining clear and distinct. This we consider to be the true positive reserve fusion. Next we determine how much prism base out that can be overcome before diplopia ensues, permitting the accommodation to function. Finally we determine when patient again picks up single vision by reducing the prism value in the rotaries. As we see it this gives us the following information—

First, the true positive reserve fusion convergence.

Second, the total positive reserve fusional and accommodative.

Third, some information as to the quality of the positive reserve.

Suppose a case shows that with 22Δ base out the line of type begins to blur, and that 10Δ more can be added before diplopia ensues, and that patient re-establishes binocular single vision at 16Δ . Our findings would be recorded as 22-32-16.

The negative reserve fusion convergence corresponds to the abduction test at infinity, with the difference that in non-presbyopic cases the accommodation is in action to the amount necessary to see clearly at the distance, test

is made. The same vertical line of type is used and patient is requested to maintain clear single vision while prism base in is added to the rotary prism units. Here again we ascertain when accommodation influences the test by determining when the vertical line of type begins to blur. Then when diplopia ensues and finally when binocular single vision is re-established. For example, if line of type blurs at 16Δ base in, diplopia at 22Δ , and patient picks up single vision at 18Δ , we would record our findings as 16-22-18. This, as we interpret the findings, gives to some extent information that the desire for single vision is reasonably strong indicating a well developed fusion faculty.

On the other hand if blurring takes place at, say, 14Δ base in, and 26Δ can be added before fusion breaks, and patient does not pick up single vision until the prisms are reduced to 7Δ base in, the data would indicate a poor desire for single vision, caused by a defect in the fusion faculty, also manifest in the accommodative convergence test by a large exophoria at the near point.

Before we further consider the significance of the data supplied by near point tests we have explained, it is necessary to make some explanation of the tonicity tests at twenty feet, or six meters.

An exophoria at distance means that the internal recti muscles must maintain binocular single vision by using positive fusion convergence to the amount of the exophoria. An esophoria at distance means that the external recti muscles maintain binocular single vision by using negative fusion convergence to the amount of the esophoria.

So we have tonic convergence very often in use for binocular single vision in the distance. This tonic convergence is either positive, negative, or nil. Positive when there is an exophoria, negative when there is esophoria, and nil when there is orthophoria.

We have then—

Tonic Convergence $\left\{ \begin{array}{l} \text{Positive when there is exophoria at} \\ \text{twenty feet.} \\ \text{Negative when there is esophoria at} \\ \text{twenty feet.} \\ \text{Nil when there is orthophoria at twen-} \\ \text{ty feet.} \end{array} \right.$

Convergence necessary—For $\frac{1}{3}$ meter patient's P. D. in centimeters multiplied by 3.

Convergence Used—Con. necessary plus exophoria at distance, or less esophoria at distance.

Fusion Convergence used—Amount of exophoria at near.

Acc. Con. Used—Con. used, less amount of exophoria at near.

Positive Reserve Fusion Con.—Amount of Fusion Con. in reserve.

Negative Reserve Fusion Con.—Ability of patient to diverge while accommodating at near point.

Total Positive Fus. Con.—Fusion Con. used plus positive fusion reserve.

Total Amplitude of Con.—Total amount of convergence from all sources: *i. e.* Con. used, plus positive reserve fusion convergence.

For a study of the accommodative convergence relationship let us take three cases. One with orthophoria at distance, one with exophoria of 4 Δ , and one with esophoria of 4 Δ . All with P. D.'s of 60 mm.

| | 1 | 2 | 3 |
|--------------------------------|-------------|-------------|-------------|
| Tonic Convergence | Nil | Pos. 4 | Neg. 4 |
| Convergence necessary for 13" | 18 | 18 | 18 |
| Convergence used at 13" | 18 | 22 | 14 |
| Fusion Convergence used at 13" | 6 Δ | 12 Δ | 0 Δ |
| Acc. Con. used at 13" | 12 Δ | 10 Δ | 14 Δ |
| Pos. Res. Fus. Con. at 13" | 21 Δ | 15 Δ | 27 Δ |
| Neg. Res. Fus. Con. at 13" | 18 Δ | 24 Δ | 12 Δ |
| Total Pos. Fus. Con. at 13" | 27 Δ | 27 Δ | 27 Δ |
| Total amplitude of Con. | 39 Δ | 37 Δ | 41 Δ |

The three cases are typical of different conditions found in every practice. In case number one, the burden of binocular single vision is properly distributed between accommodative and fusion convergence, with ample reserve to take care of the demand. In case number two, over half the convergence used is supplied by the fusion, and there is not sufficient reserve to take care of this abnormal demand. In case number three, none of the burden of convergence is supplied by fusion, therefore, the large reserve. In this case all of convergence is accompanied by the act of accommodation, typical of latent hyperopia.

In recording the data as enumerated in the foregoing cases, it is not necessary to set down the figures as we have done. All that is necessary is as follows:

Case No. 1—P. D. 60 mm

Exo. 0

Exo. 6 Pos. 21

Neg. 18

Case No. 2—P. D. 60 mm

Exo. 4

Exo. 12 Pos. 15

Neg. 24

Case No. 3—P. D. 60 mm

Eso. 4

Exo. 0 Pos. 27

Neg. 12

From the simple data recorded in these three cases all of the detail of the various convergence figures on page 13 can be figured. The P. D. gives the convergence necessary. The tonicity test gives the tonic convergence. The accommodative convergence test the fusion convergence in

use, and from this the accommodative convergence. The fusion reserves, positive and negative, supply the balance of the data.

Sheard² says, "The fusion convergence is the element most affected by ocular fatigue." Generally speaking not more than one third of the fusion convergence available can be continuously used over a long period of time; in other words, if there is a positive fusion supply of 27Δ , such as shown in case No. 1 on page 13, then one third of this is 9Δ . As the patient is using only 6Δ we would believe that the reserve or 21Δ was ample to take care of the demand amounting to 6Δ . On the other hand, if the supply is 27Δ , such as shown in case No. 2, and 12Δ of this is in constant demand, or nearly one half, then we should expect this patient to have considerable ocular fatigue when close work is attempted over a considerable period of time. This fatigue would arise from difficult and uncomfortable maintenance of binocular single vision.

The eyes are subject to the same laws of supply and demand that all other human activities and business relations are subject to. A man may be able to run one hundred yards in ten seconds. This is quite possible, many men have done it, but no man has ever run a thousand yards in one hundred seconds. He cannot use *all* of his energy for that length of time. Again a man may be able to just lift two hundred pounds, but he could not carry this weight very far. How much of this two hundred pounds could he carry for a reasonable length of time? Say, one third, about 67 lbs. This would make a fair pack for the average man. The human being cannot use all of his strength of any kind for a very long period of time.

Sheard³ in his volume on Dynamic Skiametry and Dynamic Ocular Tests says, "The great Ocular problem—the economic co-ordination of accommodation, accommo-

² Dynamic Skiametry by Charles Sheard Page 72

³ Dynamic Skiametry Page 88 Charles Sheard

dative convergence, and fusion convergence." It is one thing to see clearly, and distinctly; it is another thing to see singly. The former is accomplished by accommodation and in presbyopia by the help of convex spheres. The latter is accomplished by convergence. Both have to be done in comfort.

It would not be an exaggeration today to say that seventy-five per cent of the people use their eyes for close work seventy-five per cent of the time. If this is true, it is extremely important, that not only should the eyes be corrected for refractive errors, but that investigation be made into the convergence demands and reserves, and when found to be out of harmony the necessary steps taken to correct or relieve the deficiencies.

The presbyope is given an addition of plus sphere to take care of what the accommodation previously looked after. When that accommodation was available it was used and along with it was associated an accommodative convergence. When the accommodation is replaced with the plus sphere the accommodative convergence is decreased and the fusion convergence has to bear a greater burden for all near work in the interests of binocular single vision. So usually the presbyope manifests a large exophoria at thirteen inches. At this time of life a person uses their eyes for close work as much, if not more, than previously. The presbyope then, must have an ample quantity of fusion convergence to take care of the abnormal demand.

If for no other reason than presbyopia, the refractionist should not fail to make the near point tests. But we find in all ages that very often the demands on fusion are out of proportion to the supply, and again, that very often the accommodative centers are over-taxed. Consequently fusion convergence takes little or no part in the function of binocular single vision.

The fact that fusion convergence has to bear a greater burden in presbyopia so that the patient can enjoy bin-

ocular single vision, and that in many cases the positive fusion reserve is low, is an important reason for not forcing the patient to read at too close a distance by a too strong addition. The closer the patient has to hold the reading, the greater the convergence necessary to maintain single vision. Therefore, the already inadequate reserve is further depleted. The convex spherical addition may allow them to see distinctly, but they have great difficulty in seeing single for any length of time. It is the writer's rule to not go over $+2.50$ addition for any presbyope except where visual acuity is low, making it necessary to hold work closer so that vision is better on account of increased size of retinal images, or where the individual is small with short arms, or where the occupation necessitates a closer working point than sixteen inches. The farthest distance at which any person can see clearly with $+2.50$ added to distant findings is sixteen inches. Anything outside of this distance will be blurred providing of course the patient is given the full distant convex spherical power.

A practical demonstration that can be recommended for the purpose of studying the accommodative convergence relationship is to select any non-presbyope and with the proper distance correction in the Phoropter ascertain the amount of exophoria at thirteen inches using the horizontal line of type and spot, together with 6Δ displacing prism or Maddox Double Prism. Then add $+1.00$ D. sphere O. U., and immediately the exophoria will increase. The reason for this is, as the convex sphere is added accommodation is inhibited to just that extent. Also the convergence associated with the accommodation is inhibited, therefore, the fusion convergence that would be in use increases. Further increase of plus sphere will further increase the exophoria at near. Returning to the patient's distance correction the exophoria will be approximately what it was in the beginning. Now rotate into position a pair of -1.00 D. spheres. At once accommodation is used to overcome the concave power. Associated with

this accommodation is accommodative convergence. Therefore, the exophoria will be less at thirteen inches. Further increase of minus sphere, providing patient has accommodation to overcome the same, will still further reduce the exophoria or produce an esophoria. So to some extent the refractionist can do much to relieve uncomfortable near vision by the use of plus or minus spheres.

Now what can be done when the accommodative convergence tests, and reserve convergence tests indicate improper co-ordination and co-relation at the near point? For the purpose of making our explanation as clear as possible we shall divide the cases under four different headings:

- (1) High exophoria with low positive fusion reserve.
- (2) Insufficiency of convergence.
- (3) Esophoria
- (4) Vertical imbalances.

High Exophoria at near with Low Fusion Reserve

To intelligently consider this class of case it is advisable to make a division into presbyopes and non-presbyopes. The refractionist has at his command four procedures.

- (a) Use of Lenses.
- (b) Fusion Treatments.
- (c) Use of Prisms.
- (d) Recommendation of Surgical Interference.

Illustrative case. Man, age 50—wearing O. U. +4.00 D. spheres for reading. Complains of ocular fatigue and desire to sleep after using eyes for any length of time at close work. Examination shows:

| | O. D. | O. S. |
|----------------|--------------|-------------|
| | 44.00 at 90 | 44.25 at 95 |
| Ophthalmometer | 43.50 at 180 | 43.75 at 5 |
| | — .50 ax 180 | — .50 ax 5 |

Static R+2.00 Sphere
 L+2.00 Sphere

Dynamic R+4.00 Sphere
 L+4.00 Sphere

Subjective R+2.25 Sphere
 L+2.25 Sphere

Exo. 2 at 20 feet add.—14Δ Accommodation 2.00 D.
 abb.— 9Δ

Exo. 13 at 13" Pos. 13Δ—13Δ—2Δ
 Neg. 24Δ—24Δ—10Δ

Without doubt the ocular fatigue and tired feeling is because of a fusion supply of 26Δ of which 50% is in constant use. We can raise the reserve by stereoscopic development, which is the best thing to do, or we can lessen the demand by incorporating prisms bases in, in the reading correction. About one third of the fusion supply can be used continuously for any length of time. One third of 26 is 9 approximately. Therefore, this patient should only use 9Δ of fusion convergence as a maximum, whereas he is using 13Δ. We would if we were prescribing prisms, use about 1Δ to 1.5Δ base in for each eye in the reading. Very little can be done by altering the spherical part of such a case. The patient has got to have the hyperopia corrected for distance, and his presbyopia corrected so that he may see clearly for near. An under correction would not help the exophoric condition, because there is not sufficient accommodation to overcome either the hyperopia or the presbyopia. The best thing to do is give treatments to raise the positive reserve, and then a full correction without prism. Failing that we would prescribe:

O. U. +2.00 D. Sphere for distance.

O. U. +4.00 D. \subset 1Δ base in for reading.

If the patient were 25 years of age instead of 50 the data from routine examination would be something like this:

| | O. D. | O. S. |
|---|-------------------------------------|---------------------------|
| Ophthalmometer | 44.00 at 90 43.50 at 1.80 | 44.25 at 95 43.75 at 5 |
| | — .50 ax 180 | — .50 ax 5. |
| Static O. U. +2.00 Sphere. | | |
| Dynamic O. U. +1.50 Sphere | { Observation 20" Fixation 16" | |
| Subjective O. U. +2.00 Sph. Accommodation 9.00 D. | | |
| Exo. 2 at 20 feet | add. 14Δ abb. 9Δ | |
| Exo. 13 at 13" | Pos. 13Δ—16Δ—6Δ Neg. 22Δ—26Δ—16Δ | |

The procedure with this patient would be a prescription for O. U. +1.50 D. sphere for constant use and ⁴stereoscopic development of the fusion faculty. If treatment could not or would not be taken, and glasses were not entirely comfortable the writer would increase the convex spheres to +2.00, and combine 1Δ base in O. U. for constant use. It is worth while to point out in this case that the dynamic findings are less than static and subjective. This is not because there is less hyperopia, but for the reason that the accommodation by over activity is endeavoring to force accommodative convergence to bear its proper burden of binocular single vision. This is to the writer very important because it means that a full correction of the manifest error will be uncomfortable unless something is done to raise the positive reserve convergence or relieve the demand on fusion convergence. The former is accomplished by treatments and is preferable; the latter by prisms bases in.

⁴ Stereoscopic Development of The Fusion Faculty by Ivan S. Nott.
The Stereoscope in Ophthalmology by David W. Wells.

Insufficiency of Convergence.

There is a class of case that frequently is met with, where, all the symptoms of uncomfortable vision similar to high exophoria at near with low positive is reported. This type of case is insufficiency of convergence. The data obtained will be like the following:

Exo. $\frac{1}{2}\Delta$ to 1Δ at twenty feet

| | |
|----------------------------------|------------------------|
| Exo. — 3Δ to 5Δ at | Pos. 8—10— 6Δ |
| 13 inches | Neg. 16—18— 14Δ |

The key to the trouble in such a case is the insufficient convergence, and relief is usually obtained by developing and cultivating the positive reserve fusion convergence to at least 30Δ , but more likely 40Δ to 50Δ . The writer believes that the stereoscopic development is the best for this purpose. This type of case usually responds to treatment readily unless there is a toxemic condition, or some other constitutional disorder.

If stereoscopic or other treatment cannot be taken by the patient, prisms bases in may relieve the discomfort. It is the writer's opinion, however, that prisms bases in for convergence insufficiency is wrong practice, and only give temporary relief, if any. The one proper thing to do with such cases is the cultivation and development of sufficient convergence reserves, so that close work can be maintained without fatigue, and consequent ocular discomfort.

Esophoria.

It would seem from the growing number of cases that are visiting the refractionist, that the human race is fast becoming an esophoric and myopic one. Probably the reason for this is found in the tremendous demand made upon the eyes by our present civilization. A very large percentage of the people are engaged in close work throughout the working day, and many follow this up by using the eyes for reading and other close work for several hours at night.

Usually, but not always, esophoria at near is accompanied by an esophoria at six meters. The test at near is made with the Savage 6Δ displacing prism, or the Maddox Double Prism. The writer prefers to use both, thereby obtaining two opinions.

If we accept the idea that there should be an exophoria of from 4 to 7Δ at one third of a meter, as a physiologic or normal condition, then any exophoria less than 4Δ should be considered as a tendency to, or an actual esophoria. The writer is not particularly concerned about esophoria at near until it actually demands a prism base out to align the images. There are exceptions to this rule, but generally speaking, there is little or no uncomfortable vision at near work until there is an actual over convergence.

There is considerable that we have yet to find out about esophoria, and what is now put down on these pages may be entirely changed or somewhat altered in a very few years.

At the present time the author classifies esophoria as follows:

- (a) Accommodative.
- (b) Convergence.
- (c) Accommodative and Convergence.
- (d) Anatomical

An accommodative esophoria is the result of uncorrected hyperopia either manifest or latent or both.

A convergence esophoria is caused by the convergence acting well, but not wisely, and maybe the result of too great a stimulation to the internal recti muscles. If this condition persists the accommodation is dragged along by the convergence and we get:

An accommodative convergence esophoria, which to the writer means that there is an over stimulation to the convergence, which when persisted in for some time finally drags the accommodation along with it and then there results a "spasm" of both convergence and accommodation.

Esophoria at near or at distance, for that matter, is unquestionably the most difficult and troublesome to handle that the optometrist has to face. Very often the condition is stubborn and requires a long time to eliminate. Frequent change of glasses is necessary, sometimes convex lenses, sometimes prisms bases in, sometimes bifocals, and sometimes a combination of all these is necessary to give complete relief. On top of this, relaxation exercises or treatments are very often advisable to assist in breaking the esophoria. In this respect the author believes that the ⁵stereoscopic treatment is the best.

I have divided esophoria into three classes (*i. e.*) accommodative, convergence, and a combination of the two, which the writer calls accommodative convergence.

It is difficult to lay out the precise procedure for handling such cases because each one presents a different problem. In the following the author will attempt to outline differential data, and various methods of procedure for handling the situation.

A straight accommodative esophoria may show data as follows:

| | | |
|----------------------------------|---|-----------------------------|
| Age 26. | O. D. | O. S. |
| Ophthalmometer | 45.00 at 90 44.50 at 180 | 45.25 at 90 44.75 at 180 |
| Static | { O. D. +2.25 O. S. +2.25 } | |
| Dynamic | { O. D. +3.25 { Observation 20" O. S. +3.25 { Fixation 16" | |
| Subjective | { O. D. +1.75 O. S. +1.75 } Binocularly O. U. +2.00 | |
| At 20' Eso. 2Δ } With +2.00 Sph. | | |
| At 13" Eso. 3Δ } | | |

⁵ Stereoscopic Development of the Fusion Faculty by I. S. Nott.

At 13" Exo. 3Δ with +3.25 Sph.

Pos. Res. 24Δ—30—20Δ

Neg. Res. 12Δ—16Δ—14Δ

The Dynamic Skiametric test is the key for this case together with the fact that with distance correction esophoria at near is 3Δ, and with Dynamic findings exophoria 3Δ. In other words, accommodation is lagging behind more than normal in an endeavor to force the fusion convergence to accept its part of the responsibility of binocular single vision for close work. The slight esophoria at infinity suggests that the patient will ultimately wear a little more plus for distance, for at twenty feet there is required about 1Δ of convergence to maintain binocular single vision, and so a pair of eyes showing 1Δ of esophoria has really 2 P. D. of esophoria. The procedure for this case would be O. U. +2.50 sphere for constant wear, but better still O. U. +2.25 sphere with +1.00 added made in bifocal form. This permits distinct distant vision and comfortable reading vision.

A straight convergence esophoria may show data as follows:

| Age 19. | O. D. | O. S. |
|----------------|--------------------------|-----------------|
| Ophthalmometer | 45.75 at 95 | 45.50 at 85 |
| | 44.75 at 5 | 44.50 at 175 |
| | —1.00 ax 5 | —1.00 ax 175 |
| Static | { O. D. —.50 ax 180 | |
| | { O. S. —.50 ax 180 | |
| Dynamic | { O. D. —.50 ax 180 | Observation 20" |
| | { O. S. —.50 ax 180 | Fixation 16" |
| Subjective | { O. D. —.25— .37 ax 180 | |
| | { O. S. —.25— .37 ax 180 | |

| | |
|---------------|----------------|
| Eso. 1 at 20' | add.—20Δ—26—18 |
| | abb.— 6Δ— 6—3 |

Eso. 2Δ at 13"

Pos. Res. 28Δ—34Δ—22
Neg. Res. 12Δ—14—10

The refraction in this case both objective and subjective is similar all the way. The fact that Dynamic Skiametry does not reveal some plus sphere would indicate that accommodation is not lagging behind convergence any more than is normal. Therefore, the accommodation needs no relief at least for the present. This case is a typical over convergence, and the writer would prescribe O. U. 1Δ base in for constant wear.

This will force the convergence to relax, and if there is any latent hyperopia it will become manifest. The use of the prisms bases in may have to be continued for several months, or until the esophoria at near has disappeared. When it does some plus may become manifest, and the final correction may be O. U. +50 ax 90. Sometimes the convergence refuses to relax with 1Δ. Then relaxation treatment must be instituted, and as soon as abduction is increased more prism base in, is temporarily prescribed until the esophoria reduces or disappears. Generally speaking about one third of the abduction can be worn as prisms bases in for constant use.

An accommodative convergence esophoria would show data similar to the following:

Age 22.

| | | |
|----------------|--------------|--------------|
| Ophthalmometer | 45.50 at 105 | 45.25 at 75 |
| | 44.50 at 15 | 44.25 at 165 |
| | —1.00 ax 15 | —1.00 ax 165 |

Static

R+.25 +.50 ax 105
L+.50 +.50 ax 75

| | | |
|------------|--------------------|-----------------------------------|
| Dynamic | R+1.50 +.50 ax 105 | { Observation 20" Fixation 16" |
| | L+1.75 +.50 ax 75 | |
| Subjective | R+.50 ax. 100 | { Binocularly Con. Add + .25 |
| | L+.25 ax. 80 | |

Eso. 4 at infinity abb. 5

Eso. 2 at 13" with subjective Pos. 30—40Δ—28Δ

Exo. 4 at 13" with dynamic Neg. 12—14Δ—12Δ

As the author interprets this data there is latent hyperopia as shown by the dynamic skiametric test. The fact that the patient will not accept the full plus correction without blur at distance means that the convergence is holding the accommodation in a state of spasm, although at the near point the accommodation is lagging behind to the extent of one whole diopter. We further believe that the accommodation cannot and will not relax at infinity until the convergence domination is broken. The convergence once relaxed, the accommodation will relax too, because it has nothing to hold it.

The convergence is broken with prisms bases in, and as full a correction as possible is given for distance without blur. The writer would expect the patient to accept at least +.50 sphere more in the distance when the prisms bases in are before the eyes. It is remarkable sometimes the extra plus that can be added when the convergence is relaxed in esophoria. If enough plus can be added single vision lenses are indicated, but if the extra plus cannot be incorporated in the distance, or if with prisms bases in before the eyes the dynamic skiametry indicates more plus than originally found, then bifocals are necessary. This means as much plus as possible in the distance, also prisms base in to about one third of the abduction, and enough addition in the form of a bifocal to bring the total reading up to the full dynamic skiametry finding.

Esophoria is always a troublesome and difficult thing to handle. Sometimes plus lenses, sometimes prisms bases in, sometimes a combination of these two, and sometimes the plus spheres with prisms bases in made in bifocals. Frequent changes in lenses are necessary. As soon as relaxation of convergence is accomplished more plus sphere will be accepted in the distance, and when this happens it must be incorporated in the glasses.

The old days when we used to over correct the distance so that vision was blurred have gone. Relaxation of accommodation very seldom is attained by this method, and besides, the patient's orientation and perspective are upset when distance vision is blurred, and this results in the dissatisfaction of the patient.

There is a type of esophoria usually found in Presbyopia that the author believes to be anatomical. This type of esophoria is not associated with any accommodative disturbance, nor from convergence over stimulation. A typical case record follows:

Age 58.

| | O. D. | O. S. |
|----------------|----------------------------|---------------|
| Ophthalmometer | 44.50 — .75 | 40.25 — 85 |
| | 42.87 — 165 | 43.62 — 175 |
| | — 1.62 ax. 165 | — 2.62 ax 175 |
| Static | O. D. — .25 — .75 ax 165 | |
| | O. S. — .25 — 1.25 ax 175. | |
| Dynamic | O. D. + 2.25 — .75 ax 165 | } Obv. 16" |
| | O. S. + 2.25 — 1.25 ax 175 | |
| | | } Fix. 16" |
| Subjective | O. D. — .75 — .50 ax 135 | .8 |
| | O. S. — .25 — 1.50 ax 175 | .8 |

Eso. 11 at infinity

Exo. 5 at 13"

(Continued on next page)

Pos. 20 — 20 — 8

Neg. 20 — 20 — 6

Rx Given:

O. D. —.75 — .50 ax 150 2 out

O. S. —.25 — 1.50 ax 175 2 out

Add o. u. + 2.50 D. 3 base in

Some prism base out was required in this case to give comfortable vision for distance, but due to the reduction of Eso. 11 at six meters to Exo. 1 at thirteen inches, combined with the rather low positive reserve convergence, and particularly the quality (only 8), the prism base out in the distance had to be eliminated, and it would be of some help to have more prism base in for close work.

A pair of cement bifocals with prism segments were made up to try out, and if successful we intended ordering a pair of Ultex in B style with prism segments. The patient reported complete satisfaction and so the special Ultex were obtained.

This patient, a lawyer, had to have a double vision lens, he had been wearing a prism base out Rx, with a + 2.50 D. addition in a Kryptok bifocal, but with great discomfort. The data showed that in our opinion the prisms bases out while needed for distant vision were unnecessary for near vision.

Vertical Imbalances.

True right or left hyperphoria can be the cause of considerable discomfort, and part to a large amount of it should be corrected if comfortable binocular single vision is desired. But very often vertical imbalances are false, and are the effect of some cause that, when removed, eliminates the vertical imbalance. Ear troubles are the cause of much hyperphoria, and the patient should always be questioned about the ears when hyperphoria is present. Focal infection of sinuses, antrums, and teeth are also factors in vertical imbalance. Any of these conditions when found

to be present should of course be referred to the proper authority for attention. Sometimes in these cases it is advisable to prescribe a temporary correction involving vertical prisms, with the idea in view of removing the prism part of the prescription if the hyperphoria disappears after proper medical or dental treatment.

The writer has become so suspicious of hyperphoria that he now uses several methods to determine its presence. These are:

Displacing Prism Test at 6 meters.

Vertical Duction Tests at 6 meters.

Maddox Double Prism Test at $\frac{1}{3}$ meter.

Vertical Fusion Tests at $\frac{1}{3}$ meter.

Stereo. Test with Wells-DeZeng Phorometer using B3 Card.

The writer prefers the 10 Δ Savage displacing prism to any other test at infinity for vertical imbalances. Using an instrument which has a 10 Δ prism base in for each eye, and a red glass available for each eye, it is possible to determine the hyperphoria quickly and accurately, and do it with displacing prism over each eye. When a 6 Δ base up prism is also available over each eye for determining lateral imbalance, we have a combination that ascertains the muscular poise in a very efficient manner.

The AO-DeZeng No. 584 and No. 588 Phoroptors have these Savage displacing prisms, and also have a pair of 15 Δ rotary prism units that permit open scale readings, which are very valuable in measuring hyperphorias. A one half diopter error is easily recorded and seen on the 15 Δ unit, whereas on the 30 Δ unit this is impossible.

For measuring hyperphoria at 6 meters we recommend the following: With patient's ametropic correction in the instrument, and with P. D. set correctly and patient looking through the optical centers of the lenses, place 6 Δ

prism before left eye and red glass before the right. The patient's attention is directed to a Greek Cross about on the level with the eyes. Unless there is considerable right hyperphoria or suppression, patient will see two crosses, one red and one white. The red cross belongs to the right eye. If upper (red) cross is to the right of lower (white) cross, there is a condition of esophoria, and the amount of prism base out placed in one of the rotary prisms is a measure of the error. If the upper (red) cross is to the left of lower (white) cross there is exophoria, and the amount of prism base in is a measure of the error.

When lateral balance is determined the 10Δ base in displacing prism is rotated into position before the left eye, and the 6Δ base up removed. In the Phoropter these two prisms are placed next each other for convenience and facility in handling.

The patient now sees a red cross to the right and a white cross to the left. The red cross belongs to the right eye. If the two crosses are on the same level there is a condition of vertical orthophoria. If the red cross is higher there is a condition of left hyperphoria, and with one of the rotary prisms set in position the amount of prism base down before O. S., or base up before O. D. that will align the crosses is a measure of the error. If the red cross is lower than the white there is a condition of right hyperphoria, and the amount of prism base down before O. D., or base up before O. S. that will align the crosses is a measure of the error.

The vertical duction tests at infinity with the Phoropter can be quickly and accurately determined because of the 15Δ rotary prism units with their open scale readings. The test involves:

- Right Supraduction.
- Right Infraduction.
- Left Supraduction.
- Left Infraduction.

To make the test have patient fix a horizontal line of type or the Greek Cross, and to say "two" the moment diplopia ensues.

Prism base down before O. D. is right supraduction.

Prism base up before O. D. is right infraduction.

Prism base down before O. S. is left supraduction.

Prism base up before O. S. is left infraduction.

The difference between right supraduction and right infraduction is an indication of vertical imbalance. The same is true of the difference between left supraduction and left infraduction.

For example:

| | |
|--------------------------|--------------------------|
| R. Supra. $3\frac{1}{2}$ | L. Supra. $2\frac{1}{2}$ |
| R. Infra. 2 | L. Infra. 4 |

Such data would indicate a right hyperphoria of $1\frac{1}{2}\Delta$. The vertical fusion tests at $\frac{1}{3}$ meter are taken in the same manner using the horizontal line of type—"Read these words letter by letter."

The Maddox Double Prism test at $\frac{1}{3}$ meter for vertical imbalance is very reliable, and is made at the same time as the accommodative convergence test. With Maddox prism before left eye, with base line of prism exactly bisecting the pupil, and set at precise horizontal, the patient will see two lines of type and two spots. It is best to occlude right eye until proper adjustment is made, so that patient sees two lines of type equally clear. When right eye is uncovered there is a third line and dot in between the other two. Sufficient prism base in or base out, whichever the case may be, is placed in one rotary prism until spots are all in vertical alignment. If the center spot is nearer the top spot, there is a condition of left hyperphoria, and the amount of prism base down before O. S. or base up before O. D. that places the center spot midway between top and bottom is a measure of the error.

If the center spot is nearer the bottom spot, there is a condition of right hyperphoria, and the amount of prism base down before O. D. or base up before O. S. that places the center spot midway between top and bottom is a measure of the error.

In making this test for vertical imbalance, the center spot may swing to left or right after any incorporation of prism for measuring hyperphoria. This should be taken care of by changing the horizontal prism until the three spots are in a vertical line, and of course if the change in horizontal prism affects the position vertically of the center spot it is adjusted to proper position midway between top and bottom. This Maddox Double Prism test is in the author's opinion the best for making the accommodative convergence and hyperphoria tests at near point, as it permits the examiner to make the tests "all in one go."

One further test of considerable value for determination of hyperphoria is the stereoscopic examination using Wells-DeZeng Phorometer Stereoscope and B3 card. With patient's ametropic correction before the eyes, properly centered either in glasses or in instrument, and with $+10.00$ D. spheres in instrument, the B3 card is placed in holder. If patient has binocular single vision the left eye will see a red vertical line, and the right eye will see a horizontal black line. The red line is divided into 5 mm sections, letters are used to mark each division, the central one with black line being G. As the chart is at the principal focus of the $+10.00$ D. spheres (*i. e.* 100 mm) then a displacement of 1% or 1 mm represents 1Δ therefore, 5 mm equals 5Δ.

If the black line cuts the red at the letter G there is no hyperphoria. If black line cuts at letter H there is 5Δ of right hyperphoria. If black line cuts at F there is 5Δ of left hyperphoria. The exact amount may be measured by using one of the rotary prisms, and placing prism base up or down until black line cuts red exactly at G.

In making this stereoscopic test for vertical imbalance several things should be watched to insure accurate results.

The +10.00 D. lenses must be correctly centered, that is to say, the optical centers must coincide with the geometrical centers. The card holder must be set at exactly horizontal when bubble of spirit level is central. It is best for the refractionist to check the instrument occasionally in this respect by using himself or some other person as a patient who is free from hyperphoria.

Another thing to know is the model of instrument used. One model has the card holder attached to the instrument proper immediately beneath the spirit level, with two pins that fit into two holes. In this model the card holder tilts when the instrument is tilted through the thumb screw that operates the spirit level. With this particular combination the horizontal alignment of patient's eyes is not important, although it is best to have the eyes looking through the approximate centers of the +10.00 D. lenses.

A second model of instrument has the card holder attached to the instrument proper at the large brass screw about one inch below the spirit level. In this combination the card holder remains stationary when the instrument is tilted through the thumb screw that operates the spirit level. It is most important, therefore, that patient's eyes be looking exactly through the optical centers of the +10.00 D. lenses; and that spirit level be adjusted for exact horizontal of instrument. A 1 mm decentration vertically in this model of instrument means an introduction of a 2Δ base of prism in the direction of decentration.

The first model of instrument is the best for determining hyperphoria stereoscopically, as the only items to be sure of it correctly centered lenses and card holder straight and level.

A final check for vertical imbalances is the subjective one of holding from one half to two thirds of the existing error before the patient's eyes while viewing the smallest type that can be read with ametropic correction placed in a trial frame.

Suppose that all tests indicate from $1\frac{1}{2}$ to 2Δ of left hyperphoria. Starting at $\frac{3}{4}\Delta$ or 1Δ and up to $1\frac{1}{2}\Delta$ we

would endeavor to ascertain what amount of prism gave more comfortable vision. For this purpose it is desirable to have square prisms in $\frac{1}{4}\Delta$ from $\frac{1}{2}\Delta$ to, say, $1\frac{1}{2}\Delta$. With the base marked plainly these can be very conveniently held before the patient's eyes.

We have detailed at some length the various tests we make for hyperphoria because we believe that vertical imbalances are often false, and, therefore, should not be corrected unless definitely proven so with several tests. We further believe that considerable disturbance to vertical balance is caused by focal infection, particularly ear troubles. Experience has also taught us that vertical imbalance will often disappear after proper development of the fusion faculty stereoscopically. Notwithstanding all this the writer does not hesitate to prescribe some part of the hyperphoria in glasses, when we are satisfied that the imbalance is a true one and not false. We prefer to place the prism over the non-dominant eye as long as it does not exceed 2Δ or at the outside 3Δ .

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C.1

- 1- Focus ophthalmometer for own eye.
- 2- Get the ~~visual~~ images in the center of the field by the lens on the right side.
- 3- Overlap the visual images by turning the pan counter clockwise until the black line is continuous. The instrument is in the primary meridian.
- 4- Measure the diaphic power by separating the mires and bringing them together again by a point of tangency.
- 5- Record reading in that meridian.
- 6- Rotate telescope 90° (secondary). If the mires are tangent in the secondary, the cornea is spherical.
- 7- Create tangency in secondary meridian.
- 8- Record readings.
Correct by a $\frac{1}{2}$ cyl axis in weaker meridian.
- 9- When the visual images overlap in the secondary, it shows that the vertical meridian is the stronger in diaphic power.